HIGH-CAPACITY ULTRASONIC COMPOSITE OSCILLATING DEVICE

[0001]

Technical Field

The present invention relates to a high-capacity ultrasonic composite oscillating device used in an ultrasonic processing machine or a shifter for processing (joining, cutting, grinding, deforming, and so on) metal, plastic, ceramics, electronic component and the like with oscillations.

[0002]

Background Art

In conventional, an ultrasonic composite oscillating device disclosed in JP-A-11-87437 is known in the related art.

[0003]

The related art is composed in such a manner that a composite flexure oscillating body is induced by two driving vertical transducers which are orthogonal to each other.

[0004]

However, in the related art, since excitation of a flexure oscillating rod is achieved by the two driving vertical transducers, it is impossible to provide a high-capacity (large output) vibration energy, and hence the range of application is limited as a wire bonder within 0.7 mm in wire diameter.

[0005]

Therefore, a high-capacity ultrasonic composite oscillating device has been much needed for ultrasonic processing such as spot joining, seam welding, plastic joining, or metal deformation of metal plate other than wires.

[0006]

It is an object of the present invention is to provide a high-capacity ultrasonic composite oscillating device by installing a plurality of sets of ultrasonic transducers to a disk-shaped oscillating body is formed of a material with high rigidity so that vibration loss is negligible.

[0007]

Disclosure of Invention

In order to solve the problem described above, the present invention is achieved by the inventors who have found a fact that a center portion of a disk-shaped oscillating body induces composite oscillations that follow a Lissajous track by installing a plurality of sets of ultrasonic transducers, which are driven in opposite phases when being opposed to each other, at regular interval on an outer peripheral portion of the disk-shaped oscillating body.

[0008]

The invention according to Claim 1 is a high-capacity ultrasonic composite oscillating device includes n-sets ($n \geq 2$) of bolt-tightened Langevin-type ultrasonic

transducers (hereinafter, abbreviated as BLT) having the identical characteristics disposed at regular intervals on an outer periphery portion of a disk-shaped oscillating body so as to oppose to each other, the disk-shaped oscillating body having a center portion which serves as an oscillation loop, wherein the BLTs are driven in such a manner that the opposed BLTs are driven in a opposite-phase mode respectively, and the adjacent sets of BLTs are driven in a oscillating mode in which the phase is shifted by π/n, so that composite oscillations occur at the center portion of the disk-shaped oscillating body.

[0009]

The invention according to Claim 2 is, in addition to the invention according to Claim 1, a loop segment of oscillation of an oscillating rod that oscillates in a composite flexure oscillating mode is connected to the center portion of the disk-shaped oscillating body.

[0010]

When a first pair of BLTs are oscillated vertically in opposite phases, the disk-shaped oscillating body mechanically connected to the BLTs are induced in the direction of diameter that connects axial centers of the both BLTs. A second pair of BLTs located next to the first pair are induced π/n phase behind the first pair of BLTs, and a third pair of BLTs located next to the second pair are induced π/n phase behind the second pair of BLTs, and in the same manner, the BLTs are induced to a n^{th} pair.

[0011]

The disk-shaped oscillating body is induced by the n pairs of BLTs, and the center potion thereof induces composite oscillations that follow the Lissajous track, and an oscillation output is 2n times capacity of the single BLT. By connecting the loop segment of oscillation of the oscillating rod that oscillates in the composite flexure oscillating mode to the center of the disk-shaped oscillating body, a high-capacity composite oscillation output of 2n times the single BLT can be obtained from an end of the oscillating rod.

[0012]

Therefore, by mounting a tool or a slider for ultrasonic composite oscillation processing according to the object at the end of the oscillating rod, a high-capacity ultrasonic composite oscillation processing machine or a shifter can be provided.

[0013]

Brief Description of the Drawings

Fig. 1 is a block diagram showing a principle of a high-capacity ultrasonic composite oscillating device according to the present invention.

Fig 2 is an appearance view of a configuration of an oscillating system.

Fig. 3 is a measured drawing showing an oscillating mode of a center of the end of an oscillating rod.

[0014]

Best Mode for Carrying Out the Invention

As shown in Fig. 1, three sets (n=3) of BLTs 1, 1′, 2, 2′ and 3, 3′ are arranged at regular intervals on an outer peripheral portion of a disk-shaped oscillating member 4. As shown in Fig. 2, an oscillating rod 5 that is induced in a composite flexure oscillating mode is connected to a center portion of the disk so as to be perpendicular to the disk-shaped oscillating body. Since each portions in an oscillating system, shown in Fig. 2, are all connected with center bolts (not shown), a structure in high rigidity is achieved.

[0015]

Each BLT is formed into a bolt-tightened Langevin structure in which an electrostrictive element 6 supported by metal blocks from both sides. The six BLTs used here have the same vibration characteristics.

[0016]

A pair of opposing BLTs 1, 1′ are connected to an oscillator 13, an electric power amplifier with a phase shifter 10 and an output transformer 7, and electric signals of opposite phase from each other are applied by the action of the output transformer 7. Therefore, when the BLT 1 is in a resilient oscillating mode 15 in which the BLT 1 is expanded by the electric signal, the BLT 1′ is in a resilient oscillating mode 16 in which the BLT is contracted. In this case, the center of the disk-shaped oscillating body 4 is displaced from the BLT 1 toward the

BLT 1′. An oscillating mode of the BLT1 → the disk-shaped oscillating body 4 → BLT 1′ is as indicated by reference numeral 14, and the oscillating mode of a center of a joint portion between the disk-shaped oscillating body and the oscillating rod is an oscillating mode 17 in the direction of the axial center of the BLTs 1, 1′.

[0017]

The BLTs 2, 2′ are driven $\pi/3$ phase behind the driving of the BLTs 1, 1′ by an electric power amplifier with a phase shifter 11 and an output transformer 8, and the BLTs 3, 3′ are driven further $\pi/3$ phase behind with an electric power amplifier with a phase shifter 12 and an output transformer 9.

[0018]

The center portion of the disk-shaped oscillating body 4 induces composite oscillations which follow a Lissajous track by a vector sum of oscillations of three sets of BLTs.

[0019]

Therefore, the oscillating rod 5 is induced by the composite oscillations induced by the disk-shaped oscillating body 4, and the oscillating mode at the end thereof is an oval oscillation as shown in fig 3. The oval oscillation track is caused by a slight difference in drive voltage and resonance frequency among the respective BLTs, which can be corrected into a circular shape by adjusting the drive voltages and the drive phases of the electric power amplifiers with a phase shifter.

[0020]

In Fig. 1, assuming that the material of the disk-shaped oscillating body 4 is iron and steel S45C (126 mm in diameter, 40mm in thickness), the vertical resonance frequencies of the respective BLTs are 27 kHz (40 mm in diameter), the material of the oscillating rod 5 is iron and steel S45C (40 mm in diameter, 366 mm in length) and the drive voltages of the respective BLTs are 150 Vrms, the composite oscillating displacement amplitude at the end of the oscillating rod 5 was 4.5 μm.

[0021]

The operation in the present embodiment is as follows.

Signals from the oscillator 13 which is synchronized with the resonance frequency of the BLTs are shifted in phase by π/n in sequence by the electric power amplifiers with a phase shifter 10, 11, 12 and the output signals are applied to the output transformers 7, 8, 9. These signals are applied to the respective sets of BLTs in the form of two signals of in opposite phase modes by the transformers with an intermediate tap 7, 8, 9.

[0022]

The BLT converts the electric signal into a mechanical resilient oscillation, and drives the disk-shaped oscillating body 4. The center of the disk-shaped oscillating body forms a loop segment of oscillation and induces composite oscillations, and an oscillation output thereof is 6 times that of the single BLT.

[0023]

The oscillating rod 5 connected to the center of the disk-shaped oscillating body 4 is induced by the composite oscillations of the center of the disk-shaped oscillating body, and the end thereof generates composite oscillations whose output is 6 times that of the single BLT, whereby a high-capacity ultrasonic composite oscillating device is realized.

[0024]

Although the embodiment of the present invention has been described referring to the drawings, the detailed configuration of the present invention is not limited to the present embodiment, and modifications in design without departing from the scope of the present invention is also included in the present invention. For example, the oscillation amplitude can be set as desired by changing the thickness of a vertical oscillating node of the disk-shaped oscillating body, or by changing the diameter of a node surface of the oscillating rod (shouldered oscillating body, and so on).

[0025]

The positions of installation of the respective BLTs do not have to be necessarily the regular intervals, and the positions of installation can be changed as needed.

[0026]

Although the transformers with an intermediate tap are used for the pair of BLTs that are driven in the opposite

phase modes in the embodiment, the electric signals may be applied in the same phase if the directions of polarization of the electrostrictive elements that constitute the BLTs are set to the directions opposite from each other, so that the transformers with an intermediate tap are not necessary.

[0027]

Furthermore, by connecting M-pieces of the disk-shaped oscillating bodies each having a number of BLT transducers disposed on the outer peripheral portions thereof in series with oscillating rods while synchronizing oscillation phases and driving the BLT transducers of the respective disk-shaped oscillating bodies in parallel, an M-times high-capacity ultrasonic composite oscillating device is achieved.

[0028]

Alternatively, by changing the drive phases of the respective opposed sets to drive the center of the disk-shaped oscillating body as the oscillation loop and the oscillating node, the oscillating rod disposed at the center portion of the disk can be driven in flexure oscillations and vertical oscillations, whereby two-dimensional and three-dimensional composite oscillations at the end portion of the oscillating rod are achieved.

[0029]

Also, by installing a number of BLTs on the composite oscillating rod while considering the oscillation phases, a high-capacity composite oscillation source can be

configured.

[0030]

These ultrasonic composite oscillation sources may be configured into a feedback oscillator of a resonance-frequency automatic tracking type, and may be configured to control the oscillation amplitude and the oscillation output constant by employing an output of an oscillation detector disposed at an adequate position on the oscillating body or by detecting and employing a motional admittance of the oscillation source.

[0031]

The drive frequencies of the respective sets of BLTs do not have to be necessarily the same, and the same effects may be achieved for the object such as bonding even when an envelop curve is not an oval or a circle, but is a composite oscillation track of square or rectangular shape.

[0032]

Industrial Applicability

As described thus far, according to the present invention, the high-capacity ultrasonic composite oscillating device with the oscillating body with high rigidity can be obtained.